10 Quantifying the Health Benefits of Reducing Ozone Exposure

The objectives of this chapter are to quantify the adverse health effects of current ozone levels in California by estimating the health benefits that would accrue from a hypothetical control strategy that achieves the proposed ambient air quality standards for ozone. There have been several recent published efforts to estimate the health benefits associated with reducing population exposures to ozone (U.S. Environmental Protection Agency 1999; Levy et al. 2000; Anderson et al. 2004). Numerous studies conducted in the United States and other countries point to the adverse health effects from exposure to ozone. The effects from short-term exposure include, but are not limited to: hospital admissions for respiratory causes, emergency-room visits for asthma, minor restricted activity days, acute respiratory symptoms, exacerbation of asthma, and premature mortality (National Research Council 2002; U.S. Environmental Protection Agency 2004). In addition, there is more limited evidence that long-term exposure to ozone may result in new cases of asthma and premature mortality. Below we describe the methods, data, results and uncertainties involved with estimating the health benefits of the proposed California ambient air quality standards.

10.1 Health Effects Estimation Approach

Section 812 of the federal Clean Air Act required the U.S. EPA to conduct an analysis of the health benefits of current federal air pollution regulations, which resulted in a report to the U.S. Congress (U.S. EPA, 1999). These efforts have undergone years of public review and comment as well as full peer review by the U.S. EPA's independent Science Advisory Board. We have, therefore, drawn considerably from prior efforts at the federal level, particularly in the development of concentration-response functions. We have also added California-specific studies, whenever possible, as well as studies published from around the world since the U.S. EPA report. The selection of the studies and functions to include in our analysis has undergone review by several independent experts on the subject of air pollution and health.

Estimating the health benefits associated with reductions in levels of ambient ozone involves four elements:

1. Estimates of the changes in ozone concentrations due to a hypothetical control strategy.
2. Estimates of the number of people exposed to ozone.
3. Baseline incidence of the adverse health outcomes associated with ozone.
4. Concentration-response (CR) functions that link changes in ozone concentrations with changes in the incidence of adverse health effects. These functions produce a beta coefficient, indicating the percent reduction in a given health outcome due to a unit change in ozone.

Ultimately, the product of these elements generates estimates of the expected number of avoided adverse health outcomes associated with a hypothetical control strategy to reduce current levels of ozone to the proposed standard. Each of these elements is discussed below. Our methods make use of U.S. EPA's development of the Environmental Benefits Mapping and Analysis Program (BenMAP) with modifications where appropriate to reflect the application to California's setting and more recent studies. In addition, we have derived substantial material from other previous health impact studies including the U.S. EPA estimates of health benefits of the Clean Air Act (U.S. EPA, 1999), the World Health Organization (WHO) meta-analysis of ozone health effects (Anderson et al. 2004), and the Levy et al. (2001) analysis of the public health benefits of reducing ozone.

10.2 Exposure Estimation and Assumptions

The estimation of ozone exposure involves two key elements: assessing changes in ozone concentrations, and estimating the population exposed to these changes in ozone levels.

To assess the changes in the current ozone concentrations necessary to achieve the proposed standards, we first determined the State design value, the benchmark used for attainment status. The State design value is the Expected Peak Day Concentration, the value that reflects the highest concentration expected to occur on any given year based on the past three years of data. The use of three years reduces the effect of an anomalous year. Details on how the State design values are calculated are presented in Chapter 7. Because the designations of the air quality standards are done mostly at the air basin level, the design value for the basin was used for all counties within the basin.

Monitoring data for 2001 to 2003 were used from all monitors in the State meeting quality assurance criteria for valid data extracted from the ARB ADAM database (ARB, 2004). Chapter 7 provides detailed analyses of exposure to ozone in California.

To calculate changes in exposure to ozone that reflect a hypothetical attainment of the proposed ambient air quality standards, a proportional linear rollback procedure was used. Under real-world conditions, control strategies will likely have some impact on days with low and moderate levels of ozone, as well as on days with high levels. Our rollback procedure reflects this observation. Details on the changes in the distribution of ozone concentrations over time are provided in the Appendix.

Design Value Rollback Method

To assess the daily reductions in current ozone concentrations estimated to result at all monitoring sites when the standards are achieved, rollback factors from the 1-hour and 8-hour ozone design values to the applicable standard were calculated for each air basin. The ozone design value selected was the highest for the three-year period (2001 to 2003). An uncontrollable ozone concentration of 0.04 ppm (see Chapter 4) was factored into the calculation of the rollback factor (see below). This represents the average daily one-hour maximum background ozone concentration. The rollback factor was assumed to apply to each site in the air basin for every day in a given year.

This methodology assumed that under the hypothetical attainment setting, all ozone observations within an air basin were subjected to the same percentage rollback factor based on the basin's three-year high value. To investigate the plausibility of this assumption, we examined the trends in the annual distributions of the 1-hour and 8-hour concentrations of ozone in the South Coast Air Basin (SoCAB). Due to its population and current ozone levels, a significant proportion of statewide health benefits are projected to accrue in the SoCAB. For this region, the downward trend was consistent for both 1-hour and 8-hour concentrations from the 1980s to current levels. The maximum, the 90th, 80th, 70th, 60th, 50th and 40th percentiles from the annual distribution of the basin's daily high concentrations as well as the individual site's daily highs show a consistent downward trend from the 1980s. More importantly, when we examined the rate of change in the concentrations above background from the 1980s, it was similar among the percentiles. This analysis justifies our application of a constant percentage rollback to all sites within an air basin. Results for several representative sites used in this analysis of ozone trends can be found in the appendix to this chapter.

Roll-Back Procedure

For each monitoring site in the State, the rollback factor necessary to move from the basin-high value to the proposed standard was calculated for both the 1- and 8-hour averages. These rollback factors were then applied on a site–by-site basis to the ozone readings for every day. The difference between the observed value and the rolled-back value was calculated for each day of the year.

Health effects were then estimated for each day in a given year, summed across sites over the year, and then averaged over the three years of data. We also ensured that no benefits would be calculated for any day with an average concentration at or below the assumed background ozone level of 0.04 ppm. For the technical reader, the mathematical formulae for our rollback procedure are provided in the Appendix.

10.2.3 Estimation of Exposed Population

To estimate the number of people exposed to the ozone changes observed at each monitoring site, the county population was divided by the number of monitoring sites in a given county. This assumes that the population is equally distributed around each monitoring site. We used county population data from the year 2000 census. For further details, see the Appendix to this chapter.

10.3 Estimates of the Baseline Incidence of Adverse Health Outcomes

The health effect baseline incidences are the number of health events per year per unit population. In this analysis, all baseline incidence rates except those for school absenteeism were taken from U.S. EPA's BenMAP.

For mortality, the incidence rates were obtained from the U.S. Centers for Disease Control (CDC) derived from the U.S. death records and U.S. Census Bureau. Regional hospitalization counts were obtained from the National Center for Health Statistics (NCHS) National Hospital Discharge Survey (NHDS). Per capita hospitalizations were calculated by dividing these counts by the estimated county population estimates derived from the U.S. Census Bureau and the population projections used by NHDS. Hospitalization rates for all respiratory causes included ICD-9 codes 460-519. Similarly, regional asthma emergency room visit counts were obtained from the National Ambulatory Medical Care Survey (NHAMCS), combined with population estimates from the 2000 U.S. Census to obtain rates. Illness-related school loss baseline incidence rates were based on Hall et al. (2003). Ostro and Rothschild (1989) provided the estimated rate for minor restricted activity days.

The assumed incidence rates are summarized in Table 10-16 in the Appendix to this chapter. All counties and sites within each county were assumed to have the same incidence rate for a given population age group.

10.4 Concentration-Response Functions

Concentration-response (CR) functions are equations that relate the change in the number of adverse health effect incidences in a population to a change in pollutant concentration experienced by that population. As reviewed in Chapter 12, a wide range of adverse health effects has been associated with exposure to current ambient concentrations of ozone. Developing concentration-response functions from this vast and not fully consistent literature is a difficult task and ultimately involves subjective evaluations. In this section, we aim to provide a fair and accurate reflection of the current scientific literature. We also aim to provide enough detail so that others may fully evaluate our assumptions and methodology. Below, we provide CR functions for effects of short-term exposure on premature mortality, hospital admissions for respiratory disease, emergency room visits for asthma, school absenteeism, and minor restrictions in activity. Although other effects have been related to ozone exposure – such as asthma exacerbations, respiratory symptoms, hospital admissions for cardiovascular disease with short-term exposures, and mortality and asthma onset associated with long-term exposure (i.e., several years) – we determined that the existing evidence was either insufficient or too uncertain to serve as a basis for quantitative CR function estimates. A good example is asthma exacerbations for which several studies have reported associations with ozone. However, different subgroups of asthmatics and different outcome measures were used, making it difficult to develop consensus estimates.

Besides the primary studies, some CR functions were developed from previous estimates of the health impacts of ozone exposures. Sources for these studies include the U.S. EPA estimates of the health effects associated with the Clean Air Act under Section 812 (U.S. EPA, 1999), the World Health Organization (WHO) meta-analyses on ozone (Anderson et al., 2004), and the Levy et al. (2001) analysis of the public health benefits of reducing ozone.

This section discusses some factors that impact health effect estimates and outlines the epidemiological studies that were used for the basis of the CR functions.

10.4.1 Conversions for Ozone Measurements of Various Averaging Times

Most health studies considered in our analysis were conducted with ozone levels measured as 1-hour maximum or 8-hour maximum. However, there were some studies that measured ozone averaged over other time increments. Since these studies were conducted throughout the United States and other parts of the world, a national average of adjustment factors were used to convert all measurements to 1-hour and 8-hour averages (Schwartz 1997). The 1-hour maximum was assumed to be 2.5 times the 24-hour average, and 1.33 times the 8-hour average concentration. These conversion factors have been used in previous meta-analyses of the ozone epidemiological literature (Levy et al., 2001; Thurston and Ito 2001). Because the majority of studies report findings in term of ppb, CR functions were calculated per ppb, and air quality measurements were converted from ppm to ppb accordingly in the calculation of health effects.

10.4.2 Thresholds

Assumptions regarding the appropriateness of applying thresholds, and at what level, can have a major effect on health effects estimates. One important issue in estimating ozone health effects is whether it is valid to apply the CR functions throughout the range of predicted changes in ambient concentrations, even changes occurring at levels approaching the natural background concentration (without any human activity).

As reviewed in Chapter 12, most of the epidemiologic studies include very low concentrations in their analysis and no clear threshold for effects has been reported, although the issue has not been fully investigated except with reference to ER visits for asthma. These latter studies, reviewed in Section 8.3.3.2 suggest a population threshold in the range of 0.075 to 0.110 ppm for 1hr exposures, and 0.056 to 0.084 ppm (using a ratio of 1.33) for 8-hour exposures (see pg. 8-14; figure 8-1). In our approach of applying a constant percent change rollback to all of the basin-wide monitors, many of the reductions in ozone concentrations will occur below the proposed standard. Thus, for some days, our estimate of benefits will be based on ozone concentrations that are within the range of the original epidemiologic studies, but below the proposed standards.

10.4.3 Developing the Concentration-Response Function

Most of the epidemiologic studies used in our estimates have used a log-linear model to represent the relationship between ozone exposure and the health endpoint. In this case, the relationship between ozone levels and the natural logarithm of the health effect is estimated by a linear regression. This regression model generates a beta coefficient that relates the percent change in the health outcome to a unit increase in ozone. Existing studies have reported either a beta coefficient for a unit change in exposure or a relative risk (RR) for a specified change in ozone concentrations, such as 10 ppb 1-hour maximum. The RR is defined as the ratio of the health effect predicted from the higher exposure relative to some baseline exposure. Health effect estimates presented in a given study as RR for a specified change in ozone, $\Delta\ O_3$, were converted into an estimated beta using the equation:

$$\beta = \ln(RR) / \Delta O_3$$

The daily change in ozone at each monitoring site i.e., the difference between current ozone and the standard = ΔO_3) was used to calculate RR:

$$RR = \exp(\beta \Delta O_3)$$

Then, the RR estimates were used to determine the population attributable risk (PAR), which represents the proportion of the health effects in the whole population that may be prevented if the cause (ozone pollution in our case) is reduced by a given amount. Specifically,

$$PAR = (RR - 1) / RR$$

Ultimately, the estimated impact on the health outcome is calculated as follows:

$$\Delta y = PAR \times y_0 \times pop$$

where:

Δy = changes in the incidence of a health endpoint corresponding to a particular change in ozone,

y_0 = baseline incidence rate/person within a defined at-risk subgroup, and

pop = population size of the group exposed.

The parameters in the functions differ depending on the study. For example, some studies considered only members of a particular subgroup of the population, such as individuals 65 and older or children, while other studies considered the entire population in the study location. When using a CR function from an epidemiological study to estimate changes in the incidence of a health endpoint corresponding to a particular change in ozone in a location, it is important to use the appropriate parameters for the CR function. That is, the ozone averaging time, the subgroup studied, and the health endpoint should be the same as, or as close as possible to, those used in the study that estimated the CR function.

In some cases, results from several studies of the same health endpoint were combined to estimate the health effect. An inverse-variance weighting scheme was used to pool results from these studies, allowing studies with greater statistical power to receive more weight in the pooled assessment. This approach implicitly assumes that all studies are equally valid and representative of the population in question, and is the standard approach applied in many impact analysis settings.

10.4.4 Mortality from Short-Term Exposure

Chapter 12 concludes that there is sufficient evidence for an effect of daily exposure to ozone (possibly with a lag response of a day or two) on premature mortality. These effects are based on daily time-series studies of counts of daily all-cause mortality within a given city reviewed over several years. The studies control for most other factors that may impact daily mortality such as weather, time trends, seasonality, day of week, and other pollutants. The U.S. EPA is currently funding several meta-analyses of the ozone-mortality association but this information is currently not available. Therefore, we have relied on the meta-analytic efforts of the World Health Organization (WHO) (Anderson et al. 2004) with support from Levy et al. (2001) for our estimates. The WHO focused on 15 European time-series studies using all ages. Their meta-estimates indicate a relative risk of 1.003 (95% CI = 1.001 – 1.004) for a 10 $\mu g/m^3$ change in 8-hour ozone. For standard pressure (1 atmosphere) and temperature (25º C), 1 ppb ozone equals 1.96 $\mu g/m^3$. We have assumed the ratio between 1-hour and 8-hour ozone of 1.33 (Schwartz 1997). Making the conversions, the WHO estimate implies a 0.44% change in daily mortality (95% CI = 0.15 – 0.59%) per 10 ppb change in 1-hour maximum ozone.

This estimate is very similar to that produced by Levy et al. (2001). In their meta-analysis they began with 50 time-series analyses from 39 published articles. A set of very strict inclusion criteria was applied, which eliminated all but four studies. Reasons for exclusion included: studies outside the US, use of linear temperature terms (versus non-linear and better modeled temperature), lack of quantitative estimates, and failure to include particulate matter (PM) in the regression models. Ultimately, their analysis generated an estimate of 0.5% (95% CI = 0.3 – 0.7%) per 10 $\mu g/m^3$ change in 24-hour average ozone. Based on the ratio between 24-hour average and 1-hour daily maximum ozone concentration of 0.4, this converts to a 0.39% change in daily mortality per 10 ppb change in daily 1-hour maximum ozone (95% CI= 0.24-0.55%). If the criteria are loosened to include eleven more studies, the pooled estimate decreased to 0.31% per 10 ppb change in 1-hour ozone. Stieb et al. (2002) also reported a similar effect estimate (0.51% per 10 ppb change in daily 1-hour maximum ozone). Therefore, based on the currently published data, the WHO analysis effect estimate of 0.44% per 10 ppb is a reasonable central value, which is supported by the similar effect estimates of Stieb et al. (2002) and Levy et al. (2001). Likewise, our upper bound estimate is derived from the upper bound of the WHO meta-analysis of .59% per 10 ppb. This estimate was applied to all age groups. In contrast, a lower effect estimate is provided by the National

Morbidity, Mortality, and Air Pollution Study (NMMAPS). The revised analysis of this large study, conducted in 90 US cities (Dominici et al. 2003), found an effect estimate of 0.17% per 10 ppb change in 1-hour maximum ozone after conversion from the 24-hour average reported in the published study. This estimate is similar to the lower bound of the WHO estimate and represents a reasonable lower bound for purposes of estimating population health benefits. The NMMAPS study may underestimate the impact of mortality due to the modeling methodology used to control weather factors. Specifically, this effort included four different controls for temperature, where most other times-series analyses used only two or modeled extreme weather events more carefully. In comparing their results for a given city with studies of individual cities by other researchers, the NMMAPS results are usually lower.

10.4.5 Hospital Admissions for Respiratory Diseases

Studies of a possible ozone-hospitalization relationship have been conducted for a number of locations in the United States, including California. These studies use a daily time-series design and focus on hospitalizations with a first-listed discharge diagnosis attributed to diseases of the circulatory system (ICD9-CM codes 390-459) or diseases associated with the respiratory system (ICD9-CM codes 460-519). Various age groups are also considered which vary across studies. For this estimate, we rely on the meta-analysis by Thurston and Ito (1999). These authors used a random effects model using three studies from North America. The studies were Burnett et al. (1994), Thurston et al. (1994), and Burnett et al. (1997). The category of all respiratory admissions for all ages yielded an estimate of relative risk of 1.18 (95% CI= 1.10 – 1.26) per 100 ppb change in daily 1-hour maximum ozone. This category includes hospital admissions for asthma and bronchitis, so separate estimates of these outcomes are not necessary. The estimate converts to a 1.65% change in hospital admissions (95% CI = 0.95 – 2.31%) per 10 ppb change in 1-hour daily maximum ozone. This estimate was applied to all age groups. Additional studies of respiratory admissions for specific diseases or subpopulations provide additional support for the above relationship, but are not quantified to avoid double-counting. For example, Anderson et al. (1997) reported a relative risk of 1.04 (95% CI= 1.02-1.07) for hospital admissions for COPD for all ages for a 50 μ/m^3 change in ozone. This converts to 2.05% per 10 ppb change in 1-hour maximum ozone. Burnett et al. (2001) investigated respiratory hospitalizations in children under age 2, and reported a relative risk of 1.348 (95% CI= 1.193 – 1.523), which converts to a 6.6% increase in hospital admissions per 10 ppb change in 1-hour daily maximum ozone.

10.4.6 Emergency Room Visits for Asthma

Some studies have examined the relationship between air pollution and emergency room (ER) visits for pediatric asthma. Because most ER visits do not result in an admission to the hospital, we treated hospital admissions and ER visits separately, taking account of the fraction of ER patients that were admitted to the hospital. Our estimate is based on four studies which provide CR functions across the full range of ozone concentrations: Tolbert et al. (2000), Friedman et al. (2001), Jaffe et al. (2003), and Romieu et al. (1995). Tolbert et al. (2000) report an association between pediatric emergency room visits (age < 16) for asthma and ozone in Atlanta during the summers of 1993-1995. The authors report a relative risk of 1.04 (95% CI = 1.008 – 1.074) per 20 ppb change in 8-hour ozone. Friedman et al. (2001) reported an association between daily counts for asthma in two pediatric emergency departments (age 1 to 16) and ozone in Atlanta during the summer of 1996. They report a RR of 1.2 (95% CI = 0.99 – 1.56) per 50 ppb change in 1-hour maximum ozone. This model included PM10 as a co-pollutant. Jaffe et al. (2003) reported an association between ozone and emergency room visits for asthma (ages 5 to 34) among Medicaid recipients in three cities in Ohio for the summer months from 1991- 1996. Estimates for the combined three cities indicate a RR of 1.03 (1.00 – 1.06) for a 10 ppb change in the 8-hour average of ozone. Finally, Romieu et al. (1995) reported results for emergency visits for asthma (age < 16) in Mexico City from January to June, 1990. A RR of 1.43 (95% CI= 1.24 – 1.66) was obtained for a 50 ppb change in 1-hour maximum ozone.

Using an inverse variance weight, we obtained a meta-analytic result of 2.31% per 10 ppb in daily 1-hour maximum ozone with a 95% CI = 1.34 to 3.29%. This estimate was applied to children under 18. This compares to (Stieb et al. 1996), who reported an effect estimate for ER visits for asthma of 3.5% per 10 ppb change in 1-hour maximum ozone concentration for persons over 15 years of age. The association between ozone and asthma ER visits was not statistically significant for the 0 to 15 years age group.

Several studies on ER visits for asthma report a non-linear response consistent with an effect threshold (see Section 8.3.3.2 and Figure 8-1, and Section 12.2.3). The threshold level appears to be somewhere between 0.075 and 0.110 ppm for a 1-hour average (or, using a ratio of 1.33, an 8-hour average of 0.056 to 0.084). Because of this evidence for a threshold, we estimated benefits only down to thresholds of 0.075 ppm for the 1-hour and 0.056 ppm for 8-hour evaluations of ER visits for asthma. This is in contrast to the other endpoints where we calculated benefits down to background, 0.04 ppm ozone.

10.4.7 School Absences

In addition to hospital admissions and ER visits, there is considerable scientific research that has reported significant relationships between elevated ozone levels and other morbidity effects. Controlled human studies have established relationships between ozone and symptoms such as cough, pain on deep inspiration, shortness of breath, and wheeze. In addition, epidemiological research has found relationships between ozone exposure and acute infectious diseases (e.g., bronchitis, and sinusitis) and a variety of “symptom-day” categories. Some “symptom-day” studies examine excess incidences of days with identified symptoms such as wheeze, cough, or other specific upper or lower respiratory symptoms. Other studies estimate relationships with a more general description of days with adverse health impacts, such as “respiratory restricted activity days" or work loss days. We selected a few endpoints that reflect some minor morbidity effects and carefully adjusted estimates to avoid double counting (e.g., adjusted minor restricted activity days by number of asthma-related emergency room visits).

One of these studies demonstrated that absence from school was associated with ozone concentrations in a study of 1,933 fourth grade students from 12 southern California communities participating in the Children's Health Study (Gilliland et al. 2001). For illness-related absences, verified through telephone contact, further questions assessed whether the illness was respiratory or gastrointestinal, with respiratory including runny nose/sneeze, sore throat, cough, earache, wheezing, or asthma attack. Associations were observed between 8-hour average ozone and school absenteeism due to several different respiratory-related illnesses. Specifically, the authors report a 62.9% (95% CI = 18.4 - 124.1%) change in absences from all illnesses associated with a 20 ppb change in 8-hour average ozone. This provides the basis for our quantitative estimate, which was applied to all schoolchildren aged 5-17.

In calculating the change in school loss days, we assumed children did not attend school during weekends and holidays, that about 20% of students attended year-round schools, and adjusted attendance rate for each month of the year. The baseline absence rate reported by Hall et al. (2003), based on a telephone survey of school districts, was applied.

10.4.8 Minor Restricted Activity Days

Ostro and Rothschild (1989) estimated the impact of PM2.5 on the incidence of minor restricted activity days (MRADs) and respiratory-related restricted activity days (RRADs) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas. The annual national survey results used in this analysis were conducted in 1976-1981. Controlling for PM2.5, two-week average ozone concentration has a highly variable but statistically significant association with MRADs but not with RRADs. MRADs are days where people reduced their activity, but did not miss work, and can therefore be viewed as relatively minor and transient symptom days.

For our MRAD estimate, we initially reanalyzed on an individual year basis each of the six years of data from Ostro and Rothschild (1989) using their multi-pollutant model that included PM2.5. We then used an inverse variance-weighted meta-analysis to combine the six individual year results. This resulted in an estimate of a 0.112% change (95%CI = 0.046 – 0.178%) per $\mu g/m^3$ 1-hour maximum of ozone ($\mu g/m^3$). Conversion to ppb yielded an effect estimate of 2.24% change (95%CI = 0.92 – 3.56%) per 10 ppb change in 1-hour maximum ozone concentration. This estimate was applied to all adults above age 18.

10.5 Health Effects Results

Table 10-1 presents the estimated statewide annual health benefits from reducing the current (2001-2003) levels of ozone to achieve the 1-hour standard of 0.09 ppm. The 95% confidence intervals behind each central estimate reflect the uncertainty associated with the beta coefficient derived from the epidemiological studies used in the calculation. For example, the results indicate that full attainment of the proposed 1-hour standard would result in 640 fewer cases of premature mortality (95% CI =220 - 850), 3,800 fewer hospital admissions (95% CI = 2,200 – 5,400) and 3,300,000 fewer days of school loss (95% CI = 430,000 – 6,100,000) per year. Similarly, Table 10.2 presents statewide results from achieving the proposed 8-hour standard of 0.070 ppm. Generally speaking, the health benefits from attaining the 1-hour standard are greater than those associated with attaining the 8-hour standard. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-1 and 10-2 together. Tables 10-3 and 10-4 present estimates of the annual health benefits of attaining the proposed 1-hour and 8-hour standards, respectively, by air basin

10.6 Uncertainties and Limitations

There are a number of uncertainties involved in quantitatively estimating the health benefits associated with reductions in outdoor air pollution. Over time, some of these will be reduced as new research is conducted. However, some uncertainty will remain in any estimate. Below, we briefly discuss some of the major uncertainties and limitations of these estimated health benefits. These issues are discussed in more detail in Chapter 12 (also see Thurston and Ito, 1999).

To a substantial degree, the growing literature on acute ozone effects is an artifact of interest in studying acute PM effects. For example, of the 84 time-series mortality studies published since 1995, 35 studies examined PM but not ozone; 47 studies examined both PM and ozone; and only 2 studies examined ozone but not PM. In many of the multi-pollutant studies, ozone is treated primarily as a potential confounder of the PM effects under study. As a result, many of these studies lack specific hypotheses regarding mortality effects of ozone, and fail to provide the range and depth of analyses, including sensitivity analyses, that would be most useful in judging whether ozone is an independent risk factor for acute mortality. This is in contrast to morbidity studies where hypotheses regarding ozone effects on respiratory symptoms, lung function, hospitalization and ER visits, etc. have been studied with ozone treated as a key pollutant.

Several challenges and unresolved issues present themselves with respect to designing and interpreting time-series studies of ozone-related health effects. The principal challenge facing the analyst in the daily time series context is to remove bias due to confounding by short-term temporal factors operating over time scales from days to seasons. The correlation of ozone with these confounding terms tends to be higher than that for PM or other gaseous pollutants. Thus, model specifications that may be appropriate for PM, the primary focus of much of the available literature, may not necessarily be adequate for ozone. Few studies to date have thoroughly investigated these potential effects with reference to ozone, introducing an element of uncertainty into the health benefits analysis.

Of particular importance is the strong seasonal cycle for ozone, high in summer and low in winter, which is opposite to the usual cycle in daily mortality and morbidity, which is high in winter and low in summer. Inadequate control for seasonal patterns in time series analyses leads to biased effect estimates. In the case of ozone, inadequate seasonal pattern control generally yields statistically significant inverse associations between ozone and health outcomes. In contrast, for winter-peaking pollutants such as CO and NO_2, the bias is toward overly positive effect estimates. Also, temporal cycles in daily hospital admissions or emergency room visits are often considerably more episodic and variable than is usually the case for daily mortality. As a result, smoothing functions that have been developed and tuned for analyses of daily mortality data may not work as well at removing cyclic patterns from morbidity analyses.

Potential confounding by daily variations in co-pollutants and weather is another analytical issue to be considered. With respect to co-pollutants, daily variations in ozone tend not to correlate highly with most other criteria pollutants (e.g., CO, NO_2, SO_2, PM10), but may be more correlated with secondary fine particulate matter (e.g., PM2.5) measured during the summer months. Assessing the independent health effects of two pollutants that are somewhat correlated over time is problematic. However, much can be learned from the classic approach of first estimating the effects of each pollutant individually, and then estimating their effects in a two-pollutant model. For this reason, we have emphasized use of studies that have also controlled for PM.

The choice of the studies and concentration-response functions used for health impact assessment can affect the benefits estimates. Because of differences, likely related to study location, subject population, study size and duration, and analytical methods, effect estimates differ somewhat between studies. We have addressed this issue by emphasizing meta-analyses and multi-city studies, and also by presenting estimates derived from several studies.

Another issue relates to the shape of the CR function and whether there is an effect threshold. An important consideration in determining if a safe level of ozone can be identified is whether the CR relationship is linear across the full concentration range or instead shows evidence of a threshold. Among the ozone epidemiology literature, only a few studies of hospital admissions and emergency room visits have examined the shape of the CR function. These studies also provide the only epidemiologic investigations into whether or not there is an ozone effect threshold. Since only a few studies have investigated whether there is an effect threshold, and the few studies available do not cover all endpoints, the epidemiologic literature does not provide a basis for concluding whether or not there is a population effect threshold. However, many of the studies were conducted at fairly low concentrations of ambient ozone, so we are never extrapolating beyond the range of the studies. Therefore, for this analysis, we have assumed that there is no threshold for ozone effects. To the extent that there may not be health effects below the proposed ozone standard, the analysis may overestimate the impacts of reducing ozone. Thus, for the purposes of this analysis, we estimated benefits down to a background concentration of 0.04 ppm, except for emergency room visits for asthma for which a higher threshold value was used. Ultimately, about 76 - 86% of the benefits presented here accrue at ozone concentrations between the proposed standards and background. To the extent that there is a population threshold, this approach may not be appropriate. On the other hand, if a threshold model was imposed on the data, it would likely result in a higher estimated beta coefficient or slope for concentrations above the threshold, which would increase the impact per ppb for concentrations above the proposed standard. A related issue is that limited data suggest that ozone effects may be seasonal. While analysis of year round data suggests positive associations between a number of endpoints and ozone exposure, some data sets that have been analyzed seasonally report positive RR estimates for summer and negative RR estimates for winter. The cause of this has not been adequately investigated, but may be related to thresholds, differences in personal exposure between seasons, or to co-pollutant exposures. In light of this uncertainty, this analysis used year-round effect estimates. In addition, the relatively long, warm season in California may make the summer estimates more relevant than those of the winter.

A further uncertainty concerns the process used to design and implement strategies for controlling ozone-producing compounds. Such control strategies have been designed with the objective of reducing ozone episodes during worst-case meteorological conditions. In addition, basin-wide strategies have focused on the ozone concentrations at the highest (design) site in each basin. How these strategies would affect other sites during dissimilar episodes cannot be answered with certainty. Site-by-site analyses almost always have found that trends for multiple sites within a basin are very similar to each other. Similarly, monthly trends within a basin have usually proved to be similar, while the prevalence of different episode types may be markedly different for different months during the overall ozone season. (See trend analysis in the Appendix).

An additional limitation in this analysis is the inability to quantitate all possible health benefits that could be associated with achieving the proposed ozone standards, since estimates are provided for only a subset of possible adverse outcomes. For example, estimates of the effects of ozone on asthma exacerbation and long-term changes in lung function are not presented. Although there is some evidence for such effects, the available data were either too inconsistent or sparse to justify quantification of possible benefits of achieving the proposed ozone standards. To the extent that certain important health outcomes were excluded, we may have underestimated the health benefits of the proposed standards.

There is also uncertainty in the baseline rates for the investigated health outcomes in the studied population. Often, one must assume a baseline incidence level for the city or country of interest. In addition, incidence can change over time as health habits, income and other factors change.

There are likely uncertainties in the Statewide exposure assessment, and in whether the existing monitoring network provides representative estimates of exposure for the general population. The available epidemiological studies have used multiple pollutant averaging times, and we have proposed conversion ratios for 1-hour to 8-hour and 24-hour ozone concentrations based on national estimates. A preliminary examination of the California monitoring data indicates that the ratios are similar to those found in the highly populated areas of the State. However, uncertainty is added to the estimated benefits of attainment of the proposed standards to the extent the converted concentration bases differ from monitored concentrations.

10.7 Summary

The purpose of this chapter is to provide quantitative estimates of some of the health benefits that may accrue from a hypothetical control strategy that brings the State into attainment with the proposed ozone standards. This assessment should not be regarded as exhaustive, since we have provided estimates only for a selection of the most plausible effects for which there were high quality studies from which to derive CR functions. However, the results presented support the conclusion that significant public health benefits would result from Statewide attainment of the proposed ambient air quality standards for ozone.

It is estimated that attainment of the proposed ozone standards throughout California would avoid a significant number of adverse health effects each year. The higher central estimate between the values calculated for 1-hour and 8-hour averaging times is given below (see Tables 10.1 and 10.2 for the confidence intervals for each estimate):

- 640 premature deaths for all ages.
- 3,800 hospitalizations due to respiratory diseases for all ages.
- 130 emergency room visits for asthma for children under 18 years of age.
- 3.3 million school absences among children for ages 5 to 17 years of age.
- 2.6 million minor restricted activity days for adults above 18 years of age.

The reader is cautioned that since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-1 and 10-2 together.

As noted above, there are a large number of assumptions and uncertainties in this analysis. Some have to do with the study design and the statistical modeling methodologies used in the epidemiological studies from which the CR functions derive. Few studies have investigated the shape of the CR function, or whether there is a population response threshold for health endpoints other than emergency room visits for asthma. Further, but likely small, uncertainty is added by assumptions in the statewide exposure assessment. It should also be noted that since effects of chronic ozone exposure are not estimated here in terms of benefits from lowering exposure, these health benefits are underestimated.

Table 10-1 California Annual Health Benefits from Attaining 1-hour Ozone Standard of 0.09 ppm*

Health Endpoint	Population	Estimated Beta (% per 10 ppb) (95% Confidence Interval)	Avoided Incidence (cases/year) Mean (95% Confidence Interval)
Premature Mortality due to Short-term Exposures	All ages	.0043903 (.0014989 - .0058827)	640 (220 - 850)
Hospital Admissions for Respiratory Diseases	All ages	.0164145 (.0094849 - .022837)	3,800 (2,200 – 5,400)
Emergency Room Visits for Asthma	Age < 18	.0228666 (.013311 – .032370)	40 (22 – 58)
School Loss Days	Age 5-17	.2122574 (.0333618 – .329537)	3,300,000 (430,000 – 6,100,000)
Minor Restricted Activity Days	Age > 18	.0221528 (.0091579 - .034981)	2,100,000 (1,200,000 – 4,600,000)

*Base period 2001-2003. No threshold was assumed for any endpoint, except for emergency room visits for asthma, for which a threshold of 75 ppb was applied. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-1 and 10-2 together.

Table 10-2 California Annual Health Benefits from Attaining 8-hour Ozone Standard of 0.070 ppm*

Health Endpoint	Population	Estimated Beta (% per 10 ppb) (95% Confidence Interval)	Avoided Incidence (cases/year) Mean (95% Confidence Interval)
Premature Mortality due to Short-term Exposures	All ages	.0058827 (.0018982 - .0077697)	600 (190 – 800)
Hospital Admissions for Respiratory Diseases	All ages	.0217615 (.0126200 - .0302382)	3,600 (2,000 –5000)
Emergency Room Visits for Asthma	Age < 18	.0302964 (.0176434 - .0428679)	130 (72 – 180)
School Loss Days	Age 5-17	.2439832 (.0844490 – .4034611)	2,600,000 (760,000 – 5,200,000)
Minor Restricted Activity Days	Age > 18	.0293646 (.01212620 - .0462154)	2,600,000 (1,100,000 – 4,200,000)

*Base period 2001-2003. No threshold was assumed for any endpoint, except for emergency room visits for asthma, for which a threshold of 56 ppb was applied. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-1 and 10-2 together.

Table 10-3 Annual Health Benefits from Attaining 1-hour Ozone Standard of 0.09 ppm by Air Basin

Air Basin	Mortality	Hospital Admissions	Emergency Room Visits	School Absences	Minor Restricted Activity Days
Great Basin Valley	0	0	0	340	280
Lake County	0	0	0	0	0
Lake Tahoe	1	3	0	2,500	1,700
Mountain Counties	11	52	0	40,000	31,000
Mojave Desert	47	300	5	280,000	160,000
North Coast	0	0	0	370	250
North Central Coast	0	10	0	9,000	5,700
Northeast Plateau	0	0	0	0	0
South Coast	340	2,100	21	1,700,000	1,100,000
South Central Coast	17	110	1	97,000	61,000
San Diego	27	160	1	120,000	91,000
San Francisco Bay	25	150	1	100,000	89,000
San Joaquin Valley	110	610	7	650,000	320,000
Salton Sea	22	120	2	120,000	64,000
Sacramento Valley	43	220	2	170,000	120,000
Statewide	640	3,800	40	3,300,000	2,100,000

Note: Some columns may not add up to the statewide totals due to rounding. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-3 and 10-4 together. Table 10-5 should be used to estimate the maximum health benefit per air basin.

Table 10-4 Annual Health Benefits from Attaining 8-hour Ozone Standard of 0.070 ppm by Air Basin

Air Basin	Mortality	Hospital Admissions	Emergency Room Visits	School Absences	Minor Restricted Activity Days
Great Basin Valley	0	1	0	650	820
Lake County	0	0	0	35	53
Lake Tahoe	2	9	0	6,100	6,600
Mountain Counties	14	62	2	41,000	50,000
Mojave Desert	57	350	17	280,000	260,000
North Coast	0	1	0	720	750
North Central Coast	2	12	0	9,100	8,800
Northeast Plateau	0	0	0	88	140
South Coast	280	1,700	43	1,100,000	1,300,000
South Central Coast	19	120	4	92,000	91,000
San Diego	28	170	3	110,000	130,000
San Francisco Bay	15	92	3	51,000	72,000
San Joaquin Valley	120	670	42	600,000	470,000
Salton Sea	24	130	7	110,000	91,000
Sacramento Valley	43	220	6	140,000	160,000
Statewide	600	3,600	130	2,600,000	2,600,000

Note: Some columns may not add up to the totals presented in Table 10-2 due to rounding. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables 10-3 and 10-4 together. Table 10-5 should be used to estimate the maximum health benefit per air basin.

Table 10-5 Annual Health Benefits from Attaining Both 1-hour and 8-hour Ozone Standards by Air Basin

Air Basin	Mortality	Hospital Admissions	Emergency Room Visits	School Absences	Minor Restricted Activity Days
Great Basin Valley	0	1	0	650	820
Lake County	0	0	0	35	53
Lake Tahoe	2	9	0	6,100	6,600
Mountain Counties	14	62	2	41,000	50,000
Mojave Desert	57	350	17	280,000	260,000
North Coast	0	1	0	720	750
North Central Coast	2	12	0	9,100	8,800
Northeast Plateau	0	0	0	88	140
South Coast	340	2,100	43	1,700,000	1,300,000
South Central Coast	19	120	4	97,000	91,000
San Diego	28	170	3	120,000	130,000
San Francisco Bay	25	150	3	100,000	89,000
San Joaquin Valley	120	670	42	650,000	470,000
Salton Sea	24	130	7	120,000	91,000
Sacramento Valley	43	220	6	170,000	120,000

Note: The higher central estimate for the benefit values (either 1-hour or 8-hour averaging times) is given above for each endpoint by air basin.

10.8 References

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10.9 Appendix

10.9.1 Rollback Formulae

For the technical reader, the mathematical formulae for our rollback procedure follow:

Denote:

OzCurrent = current daily ozone observed value,

BasinMax = design value based on three years of measured data,

BG = background ozone of 0.04 ppm,

Std = proposed standard (0.09 ppm for 1-hour
and 0.070 ppm for 8-hour average), and

OzAttain = rolled-back ozone value in the “attainment” scenario.

First, the rollback factor (RF) was calculated for each basin as follows:

If BasinMax > Std, then RF = (BasinMax - Std) / (BasinMax – BG).

If BasinMax <= Std, then RF = 0.

Then, for all sites within the basin, the portion of the site’s current ozone levels above background was adjusted as follows:

If OzCurrent > BG, then OzAttain = BG + (1 - RF) × (OzCurrent – BG).

If OzCurrent <= BG, then OzAttain = OzCurrent.

The change in ozone concentrations is OzCurrent – OzAttain, calculated at the daily level for each site, which is the difference between the observed value and the rolled-back value for each site on each day of the year.

Note that we used the actual levels of the standards, 0.09 and 0.070 ppm, in the rollback rather than the maximal values that round to the standards as is done with air quality modeling. Such modeling usually assumes worst-case meteorology, unlike our methodology of using the three-year high value.

10.9.2 Rollback Method Development

The assumption of a constant rollback factor applied to an entire air basin was justified through an empirical analysis of the trends in the percentiles at South Coast Air Basin monitoring sites. This air basin was selected for the analysis since the air quality trends were clear, there is a range of coastal and inland environments, and a majority of benefits are projected to occur in that air basin. Figures 10-1 through 10-10 and Tables 10-6 through 10-15 provide examples of the results from that analysis, and the materials are representative of the results used for development of the rollback factor applied in the benefits analysis. In the graphs, the dotted line indicates the ozone standard, and the dashed line represents the assumed background level. Due to space limitations, the legend for every percentile line was not provided. However, the reader is advised to examine the solid lines in each graph, from top to bottom, to represent the maximum, 90th percentile, 80th percentile, 70th percentile, 60th percentile, 50th percentile, and 40th percentile of the annual distribution of ozone measurements.

Briefly, the analysis showed that since 1980, the trend in the monitored values associated with the distribution of percentiles was consistently downward, and that the relationships were relatively parallel and linear. Consequently, we assumed a constant rollback factor based on a basin's three-year high value, and applied it to all daily high values at all sites within the basin. In other words, when a control strategy is geared towards reducing the highest ozone levels in an air basin, its impact on days with low and moderate ozone levels is comparable to those days with high ozone levels.

10.9.3 Estimation of Exposed Population

To estimate the number of people exposed to the ozone changes observed at each monitoring site, the county population was divided by the number of monitoring sites in a given county. For example, suppose a county has N monitoring stations and population POP according to year 2000 census. Then we would estimate that (POP/N) persons were exposed to ozone levels at each of the N monitors within this county. The health incidences were then calculated based on the concentration-response functions relating changes in ozone concentations and exposed population for each day at each monitor.

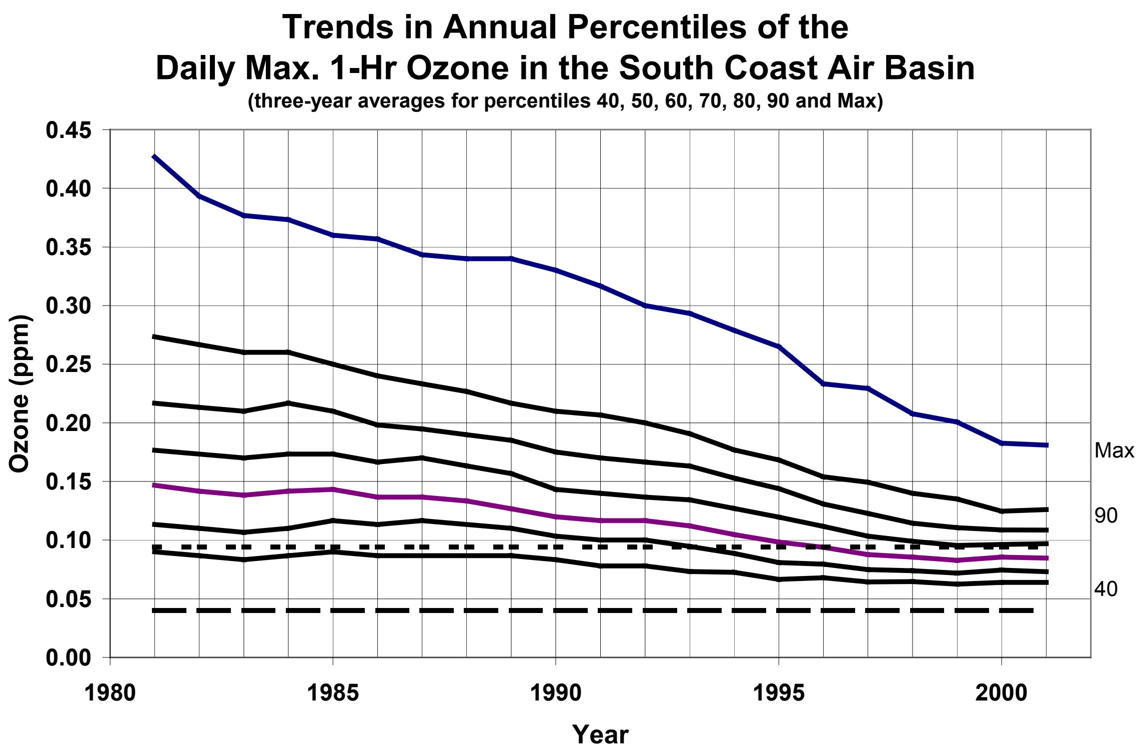

Figure 10-1 Trends in Annual Percentiles of Daily Max 1-hour Ozone in the South Coast Air Basin

Table 10-6 Summary of Trends in Annual Percentiles of the Daily Max. 1-Hr Ozone in the South Coast Air Basin

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.427**	**0.317**	**0.183**
Δ% above background		28%	63%
90th Percentile	**0.273**	**0.207**	**0.125**
Δ% above background		29%	64%
80th Percentile	**0.217**	**0.170**	**0.109**
Δ% above background		26%	61%
70th Percentile	**0.177**	**0.140**	**0.096**
Δ% above background		27%	59%
60th Percentile	**0.147**	**0.117**	**0.086**
Δ% above background		28%	57%
50th Percentile	**0.113**	**0.100**	**0.075**
Δ% above background		18%	53%
40th Percentile	**0.090**	**0.078**	**0.064**
Δ% above background		24%	52%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

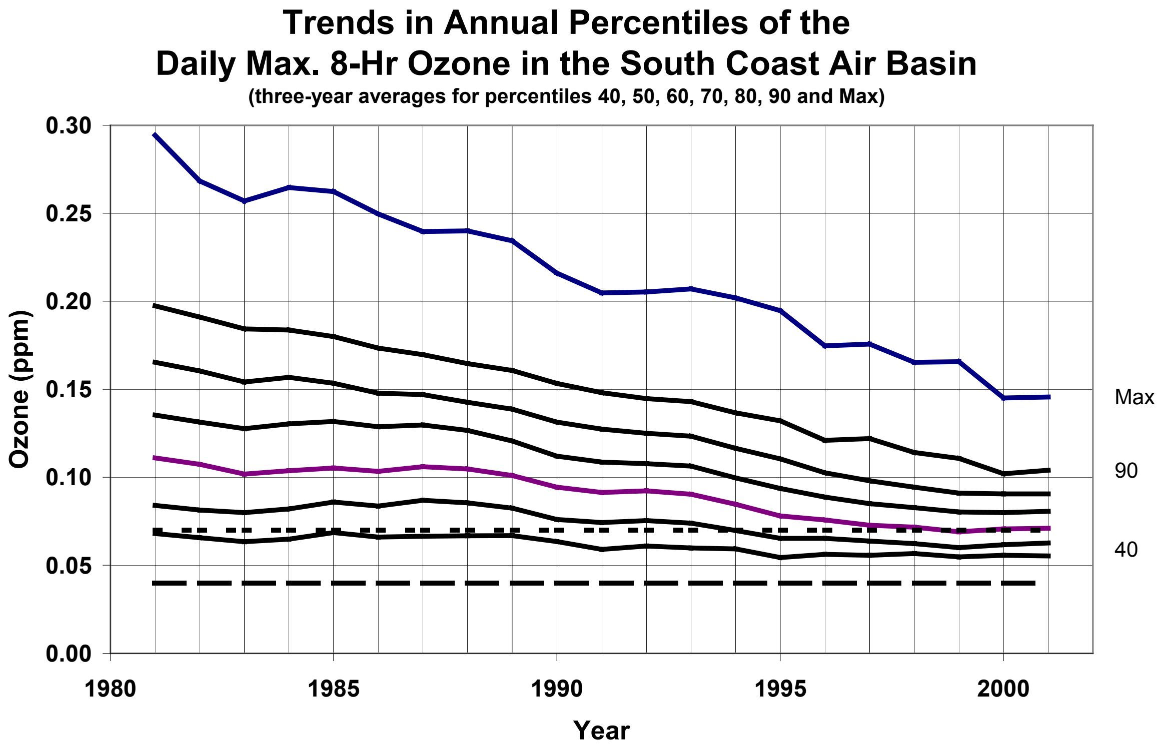

Figure 10-2 Trends in Annual Percentiles of Daily Max 8-hour Ozone in the South Coast Air Basin

Table 10-7 Summary of Trends in Annual Percentiles of the Daily Max. 8-hr Ozone in the South Coast Air Basin

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.294**	**0.205**	**0.145**
Δ% above background		35%	59%
90^{th} Percentile	**0.197**	**0.148**	**0.102**
Δ% above background		31%	61%
80^{th} Percentile	**0.165**	**0.127**	**0.091**
Δ% above background		30%	60%
70^{th} Percentile	**0.135**	**0.109**	**0.080**
Δ% above background		28%	58%
60^{th} Percentile	**0.111**	**0.091**	**0.071**
Δ% above background		28%	57%
50^{th} Percentile	**0.084**	**0.074**	**0.062**
Δ% above background		22%	51%
40^{th} Percentile	**0.068**	**0.059**	**0.056**
Δ% above background		32%	44%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background”, where background is defined as 0.04 ppm.

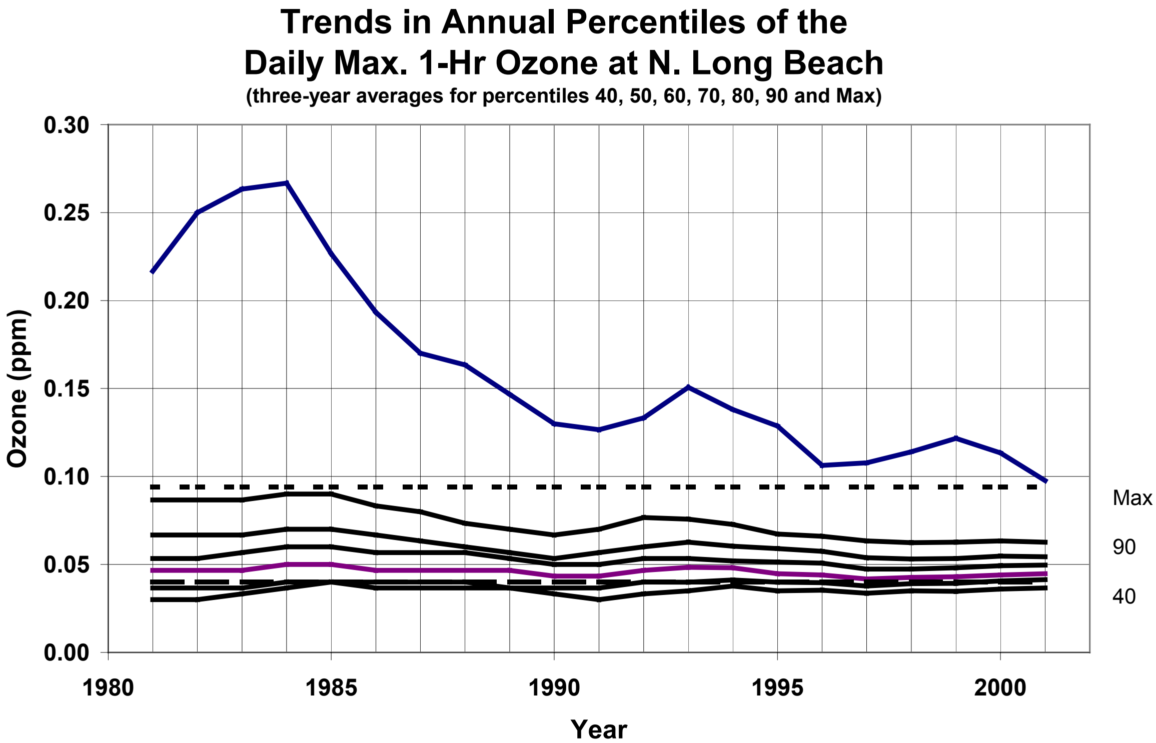

Figure 10-3 Trends in Annual Percentiles of Daily Max 1-hour Ozone at N. Long Beach

Table 10-8 Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at N. Long Beach

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.217**	**0.127**	**0.113**
Δ% above background		51%	58%
90th Percentile	**0.087**	**0.070**	**0.063**
Δ% above background		36%	50%
80th Percentile	**0.067**	**0.057**	**0.055**
Δ% above background		38%	45%
70th Percentile	**0.053**	**0.050**	**0.049**
Δ% above background		25%	30%
60th Percentile	**0.047**	**0.043**	**0.044**
Δ% above background		50%	40%
50th Percentile	**0.037**	**0.037**	**0.041**
Δ% above background		Percentiles are below background.	
40th Percentile	**0.030**	**0.030**	**0.036**
Δ% above background		Percentiles are below background.	

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

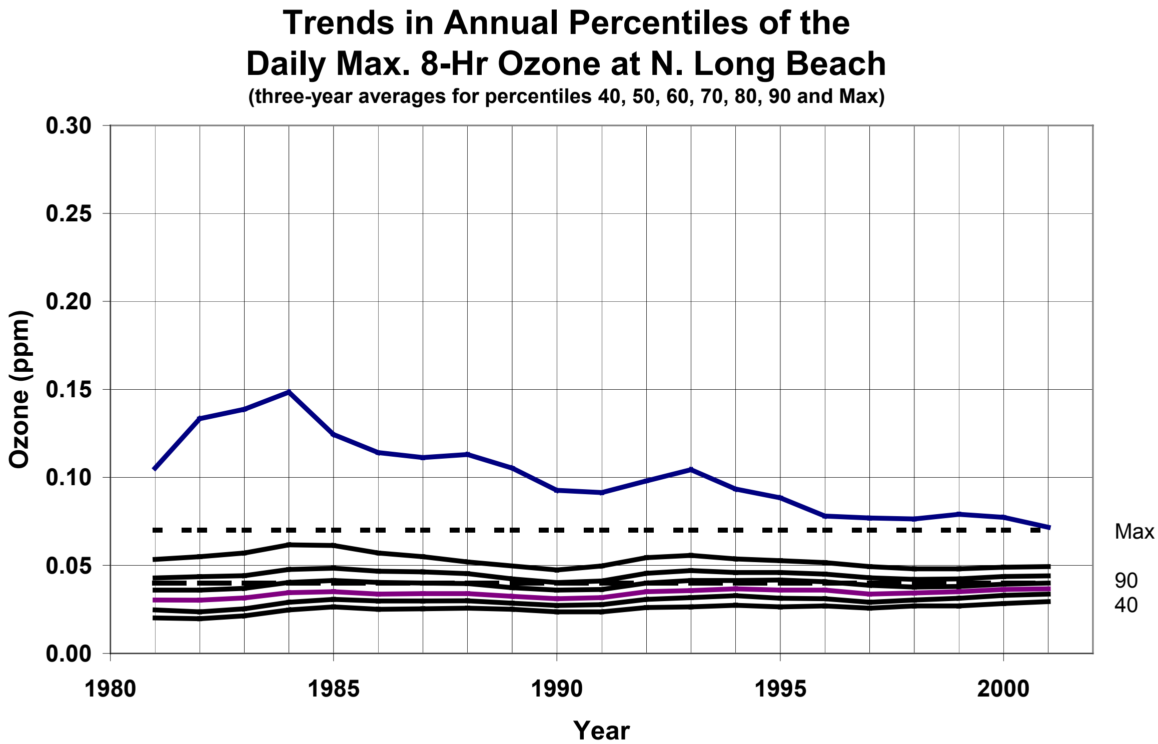

Figure 10-4 Trends in annual percentiles of daily max 8-hour ozone at N. Long Beach

Table 10-9 Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at N. Long Beach

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.105**	**0.091**	**0.077**
Δ% above background		21%	43%
90th Percentile	**0.053**	**0.050**	**0.049**
Δ% above background		28%	33%
80th Percentile	**0.043**	**0.041**	**0.044**
Δ% above background		59%	-29%
70th Percentile	**0.036**	**0.036**	**0.039**
Δ% above background		Percentiles are below background.	
60th Percentile	**0.030**	**0.032**	**0.036**
Δ% above background		Percentiles are below background.	
50th Percentile	**0.025**	**0.028**	**0.033**
Δ% above background		Percentiles are below background.	
40th Percentile	**0.020**	**0.024**	**0.028**
Δ% above background		Percentiles are below background.	

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

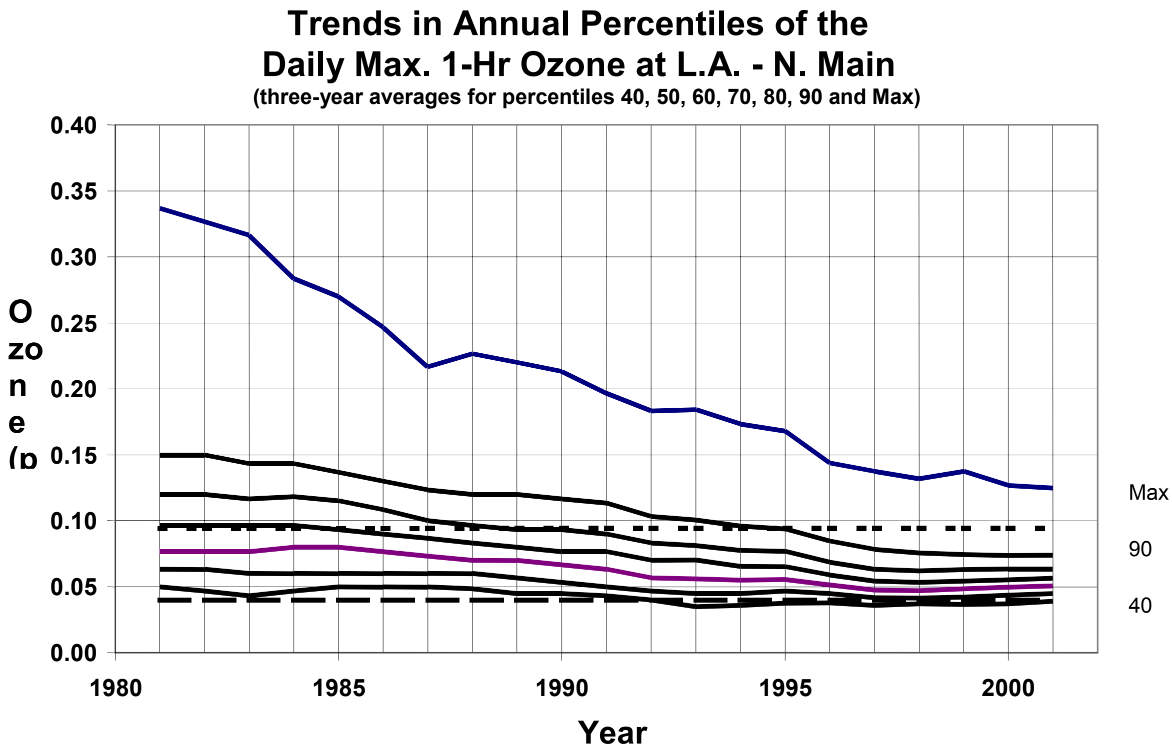

Figure 10-5 Trends in annual percentiles of daily max 1-hour ozone L.A. – N. Main

Table 10-10 Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at L.A. - N. Main

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.337**	**0.197**	**0.127**
Δ% above background		47%	71%
90th Percentile	**0.150**	**0.113**	**0.074**
Δ% above background		33%	69%
80th Percentile	**0.120**	**0.090**	**0.064**
Δ% above background		38%	70%
70th Percentile	**0.097**	**0.077**	**0.055**
Δ% above background		35%	73%
60th Percentile	**0.077**	**0.063**	**0.050**
Δ% above background		36%	74%
50th Percentile	**0.063**	**0.050**	**0.044**
Δ% above background		57%	84%
40th Percentile	**0.050**	**0.043**	**0.037**
Δ% above background		67%	100%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background”, where background is defined as 0.04 ppm.

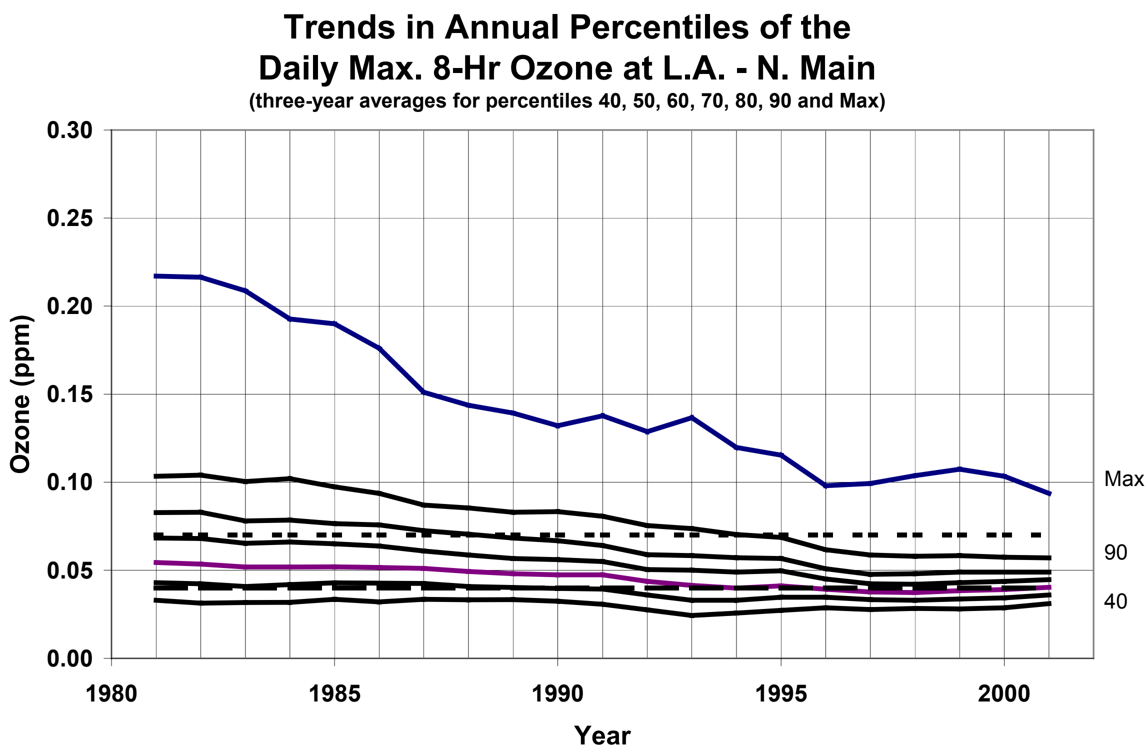

Figure 10-6 Trends in annual percentiles of daily max 8-hour ozone at L.A.-N. Main

Table 10-11 Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at L.A. - N. Main

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.217**	**0.138**	**0.103**
Δ% above background		45%	64%
90^{th} Percentile	**0.103**	**0.081**	**0.057**
Δ% above background		36%	73%
80^{th} Percentile	**0.083**	**0.064**	**0.049**
Δ% above background		44%	79%
70^{th} Percentile	**0.068**	**0.055**	**0.044**
Δ% above background		47%	87%
60^{th} Percentile	**0.054**	**0.047**	**0.039**
Δ% above background		49%	100%
50^{th} Percentile	**0.043**	**0.039**	**0.034**
Δ% above background		100%	100%
40^{th} Percentile	**0.033**	**0.031**	**0.029**
Δ% above background		Percentiles are below background.	

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

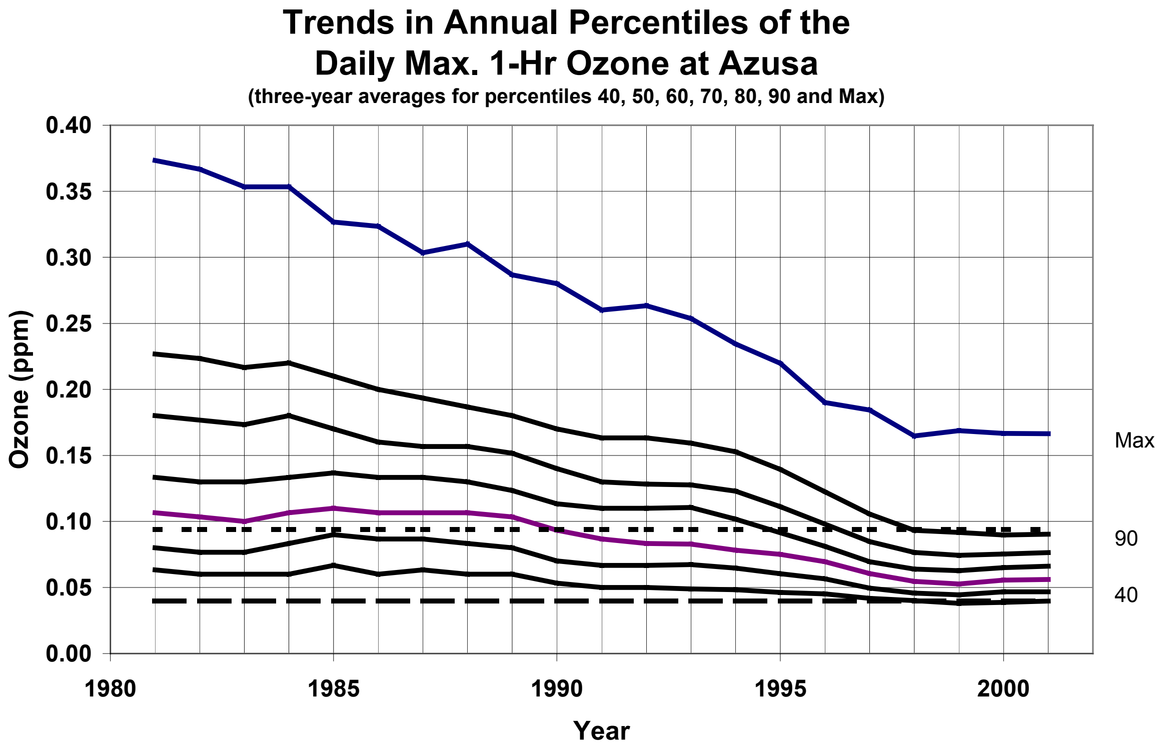

Figure 10-7 Trends in annual percentiles of daily max 1-hour ozone at Azusa

Table 10-12 Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at Azusa

Summary of Trends in Annual Percentiles of the Daily Max. 1-Hr Ozone at Azusa			
	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.373**	**0.260**	**0.167**
Δ% above background		34%	62%
90th Percentile	**0.227**	**0.163**	**0.090**
Δ% above background		34%	73%
80th Percentile	**0.180**	**0.130**	**0.075**
Δ% above background		36%	75%
70th Percentile	**0.133**	**0.110**	**0.065**
Δ% above background		25%	73%
60th Percentile	**0.107**	**0.087**	**0.056**
Δ% above background		30%	77%
50th Percentile	**0.080**	**0.067**	**0.047**
Δ% above background		33%	83%
40th Percentile	**0.063**	**0.050**	**0.039**
Δ% above background		57%	100%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

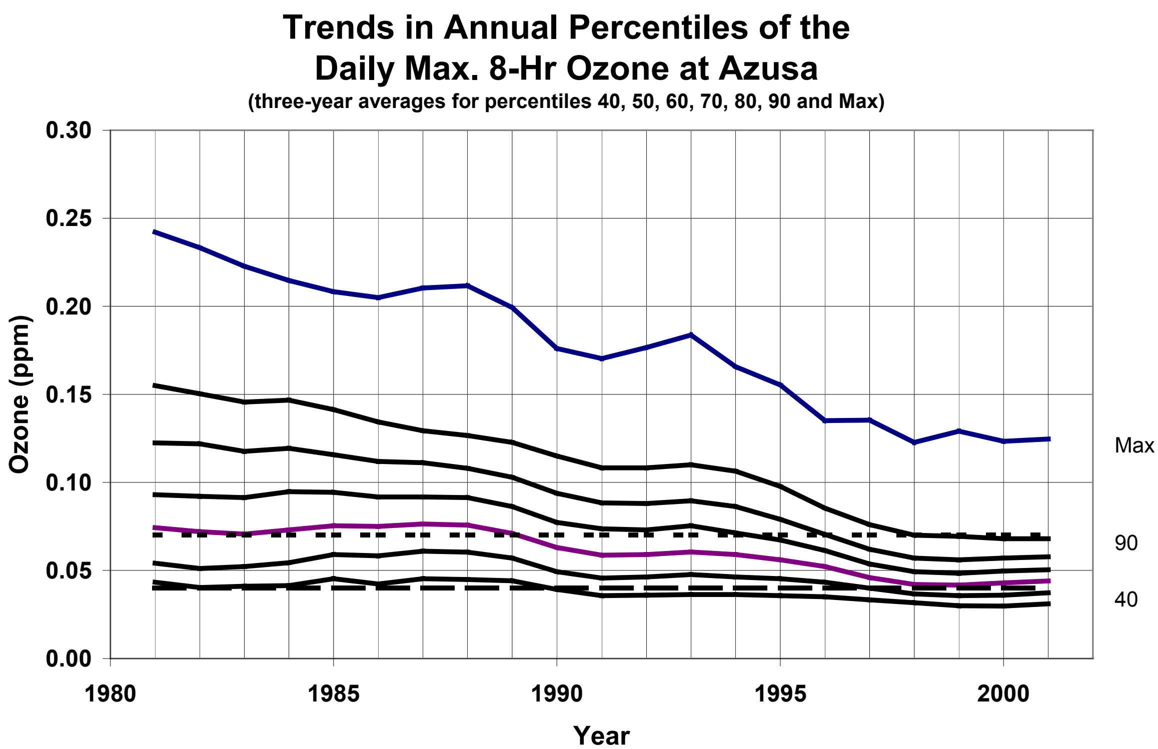

Figure 10-8 Trends in annual percentiles of daily max 8-hour ozone at Azusa

Table 10-13 Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at Azusa

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.242**	**0.170**	**0.123**
Δ% above background		35%	59%
90th Percentile	**0.155**	**0.108**	**0.068**
Δ% above background		41%	76%
80th Percentile	**0.123**	**0.088**	**0.057**
Δ% above background		41%	79%
70th Percentile	**0.093**	**0.074**	**0.050**
Δ% above background		36%	82%
60th Percentile	**0.074**	**0.059**	**0.043**
Δ% above background		46%	100%
50th Percentile	**0.054**	**0.046**	**0.036**
Δ% above background		60%	100%
40th Percentile	**0.043**	**0.036**	**0.030**
Δ% above background		100%	100%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background”, where background is defined as 0.04 ppm.

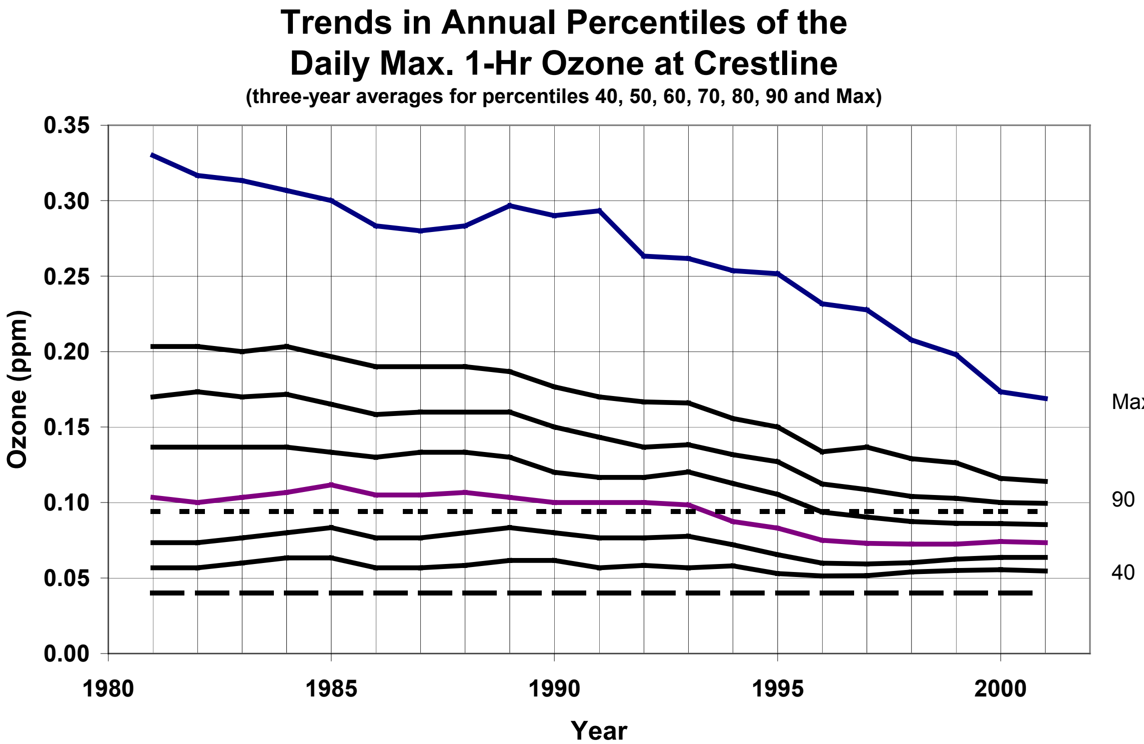

Figure 10-9 Trends in annual percentiles of daily max 1-hour ozone at Crestline

Table 10-14 Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at Crestline

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.330**	**0.293**	**0.173**
∆% above background		13%	54%
90th Percentile	**0.203**	**0.170**	**0.116**
∆% above background		20%	53%
80th Percentile	**0.170**	**0.143**	**0.100**
∆% above background		21%	54%
70th Percentile	**0.137**	**0.117**	**0.086**
∆% above background		21%	52%
60th Percentile	**0.103**	**0.100**	**0.074**
∆% above background		5%	46%
50th Percentile	**0.073**	**0.077**	**0.064**
∆% above background		-10%	29%
40th Percentile	**0.057**	**0.057**	**0.056**
∆% above background		0%	7%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

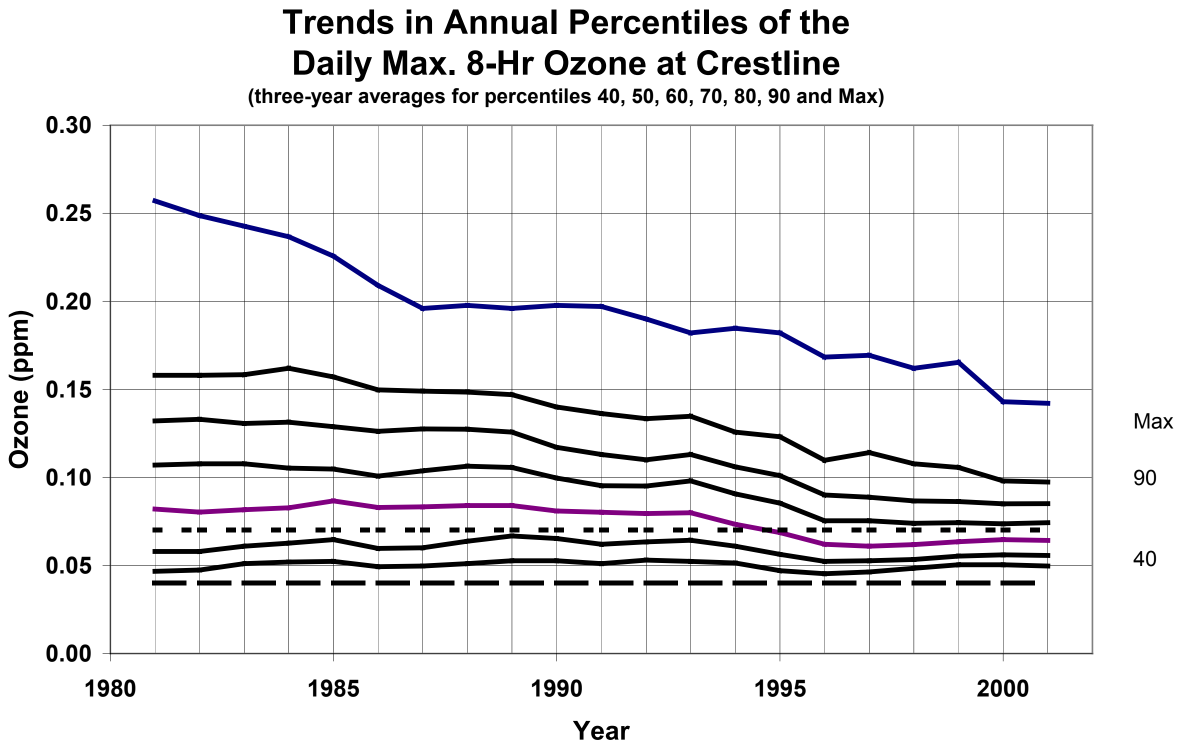

Figure 10-10 Trends in annual percentiles of daily max 8-hour ozone at Crestline

Table 10-15 Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at Crestline

	Average Value During Period		
Indicator	**1980-1982**	**1990-1992**	**2000-2002**
Maximum	**0.257**	**0.197**	**0.143**
Δ% above background		28%	53%
90^{th} Percentile	**0.158**	**0.136**	**0.098**
Δ% above background		18%	51%
80^{th} Percentile	**0.132**	**0.113**	**0.085**
Δ% above background		21%	51%
70^{th} Percentile	**0.107**	**0.095**	**0.074**
Δ% above background		17%	50%
60^{th} Percentile	**0.082**	**0.080**	**0.065**
Δ% above background		4%	41%
50^{th} Percentile	**0.058**	**0.062**	**0.056**
Δ% above background		-22%	11%
40^{th} Percentile	**0.047**	**0.051**	**0.050**
Δ% above background		-65%	-55%

note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.

Table 10-16 Baseline Incidence Rates (Incidence/1000 Persons/Year)

County Name	Mortality (Short-Term Exposures) Non-Accidental, All Ages	Hospital Admissions, All Respiratory, All Ages	ER Visits for Asthma, Age Under 18	School Loss Days, All Illness, Age 5-17	MRAD Age>18
Alameda County	6.60	10.13	3.81	5990.10	7805.39
Alpine County	7.40	10.13	3.81	5990.10	7805.39
Amador County	9.99	10.13	3.81	5990.10	7805.39
Butte County	10.40	10.13	3.81	5990.10	7805.39
Calaveras County	8.90	10.13	3.81	5990.10	7805.39
Colusa County	7.10	10.13	3.81	5990.10	7805.39
Contra Costa County	6.78	10.13	3.81	5990.10	7805.39
Del Norte County	8.41	10.13	3.81	5990.10	7805.39
El Dorado County	6.29	10.13	3.81	5990.10	7805.39
Fresno County	6.41	10.13	3.81	5990.10	7805.39
Glenn County	7.71	10.13	3.81	5990.10	7805.39
Humboldt County	8.51	10.13	3.81	5990.10	7805.39
Imperial County	5.44	10.13	3.81	5990.10	7805.39
Inyo County	11.81	10.13	3.81	5990.10	7805.39
Kern County	6.60	10.13	3.81	5990.10	7805.39
Kings County	5.66	10.13	3.81	5990.10	7805.39
Lake County	13.13	10.13	3.81	5990.10	7805.39
Lassen County	5.75	10.13	3.81	5990.10	7805.39
Los Angeles County	6.08	10.13	3.81	5990.10	7805.39
Madera County	6.35	10.13	3.81	5990.10	7805.39
Marin County	7.47	10.13	3.81	5990.10	7805.39
Mariposa County	9.48	10.13	3.81	5990.10	7805.39
Mendocino County	8.89	10.13	3.81	5990.10	7805.39
Merced County	6.29	10.13	3.81	5990.10	7805.39
Modoc County	11.62	10.13	3.81	5990.10	7805.39
Mono County	3.87	10.13	3.81	5990.10	7805.39
Monterey County	5.88	10.13	3.81	5990.10	7805.39
Napa County	10.45	10.13	3.81	5990.10	7805.39

Nevada County	8.56	10.13	3.81	5990.10	7805.39
Orange County	5.68	10.13	3.81	5990.10	7805.39
Placer County	7.00	10.13	3.81	5990.10	7805.39
Plumas County	10.08	10.13	3.81	5990.10	7805.39
Riverside County	7.37	10.13	3.81	5990.10	7805.39
Sacramento County	7.14	10.13	3.81	5990.10	7805.39
San Benito County	5.06	10.13	3.81	5990.10	7805.39
San Bernardino County	6.10	10.13	3.81	5990.10	7805.39
San Diego County	6.41	10.13	3.81	5990.10	7805.39
San Francisco County	8.78	10.13	3.81	5990.10	7805.39
San Joaquin County	6.98	10.13	3.81	5990.10	7805.39
San Luis Obispo County	7.87	10.13	3.81	5990.10	7805.39
San Mateo County	6.77	10.13	3.81	5990.10	7805.39
Santa Barbara County	6.80	10.13	3.81	5990.10	7805.39
Santa Clara County	5.19	10.13	3.81	5990.10	7805.39
Santa Cruz County	6.56	10.13	3.81	5990.10	7805.39
Shasta County	9.50	10.13	3.81	5990.10	7805.39
Sierra County	9.26	10.13	3.81	5990.10	7805.39
Siskiyou County	10.42	10.13	3.81	5990.10	7805.39
Solano County	5.90	10.13	3.81	5990.10	7805.39
Sonoma County	8.17	10.13	3.81	5990.10	7805.39
Stanislaus County	7.22	10.13	3.81	5990.10	7805.39
Sutter County	7.43	10.13	3.81	5990.10	7805.39
Tehama County	9.90	10.13	3.81	5990.10	7805.39
Trinity County	10.73	10.13	3.81	5990.10	7805.39
Tulare County	6.71	10.13	3.81	5990.10	7805.39
Tuolumne County	9.50	10.13	3.81	5990.10	7805.39
Ventura County	5.76	10.13	3.81	5990.10	7805.39
Yolo County	6.37	10.13	3.81	5990.10	7805.39
Yuba County	7.26	10.13	3.81	5990.10	7805.39